Programming Design

Introduction

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Outline

- **Computer programming**
- Our first C++ program: basic structure and **`cout`**
- Our second C++ program: variable declaration and **`cin`**
- Our third C++ program: the **`if`** and **`while`** statements
- Formatting a C++ program

Computer programming

- What are **computer programs**?
  - The elements working in computers.
  - Also known as **software**.
  - A structured combination of data and instructions used to operate a computer to produce a specific result.
- Strength: High-speed computing, large memory, etc.
- Weakness: People (programmers) need to tell them what to do.
- How may a programmer tell a computer what to do?
  - Programmers use “**programming languages**” to write codes line by line and construct “computer programs”.
- **Running a program** means executing the instructions line by line and (hopefully) achieve the programmer’s goal.

Programming languages

- People and computers talk in programming languages.
- A programming language may be a **machine language**, an **assembly language**, or a **high-level language** (or something else).
  - Machine and assembly languages: Control the hardware directly, but hard to read and program.
  - High-level languages: Easy to read and program, but need a "translator."
- Most application software are developed in **high-level languages**.
  - The language we study in this course, C++, is a high-level language.
  - Some others: Basic, Quick Basic, Visual Basic, Fortran, COBOL, Pascal, Perl, Python, Java, C#, PHP, Matlab, Objective C, R, etc.
- A **compiler** translates C++ programs into assembly programs.
  - For other high-level programs, an **interpreter** may be used instead.

The C++ programming language

- C++ is developed by Bjarne Stroustrup starting from 1979 at AT&T Bell Labs.
- C++ originates from another programming language C.
  - C is a **procedural** programming language.
  - C++ is an **object-oriented** programming (OOP) language.
- Roughly speaking, C++ is created by adding object-oriented functionalities to C.
  - For **teams** to build **large** software systems requiring a **long** time.
- C++ is (almost) a superset of C.
  - Most C programs can be complied by a C++ compiler.
- Who should learn C++?
  - Those who plan to become computer scientists/engineers.
  - Those who want to know all the (system-level) details about a program.
  - Those who want to learn other languages by themselves.

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- Our second C++ program: variable declaration and **`cin`**
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Our first C++ program

- As in most introductory computer programming courses, let’s start from the “Hello World” example:

```
#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0;
}
```

- Let’s try to compile this source code and run it!

Our first C++ program

- The program can be decomposed into four parts.
  - The preprocessor.
  - The namespace.
  - The main function block.
  - The statements.
- Some words are colored because they are C++ **reserved words** (**keywords**), which serve for special purposes.
  - We will talk about them soon.

```
#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0;
}
```

The preprocessor and namespace

- At this moment, let's ignore the first two lines.
  - They are doing some preparations before you may write your own instructions.
  - To be discussed later.
- For now, just copy them.

```
#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0;
}
```

The main function block

- A C++ Program always runs from the first line of "**the main function block**" to the last line.
  - The function is named `main()`.
  - One program, one main function.
- A pair of braces (curly brackets) defines a **block**.
  - Within `{` and `return 0;`, we write our statements to tell the program what to do.
- For now, just copy them.

```
#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0;
}
```

Statements

- There are always some **statements** in the main function.
  - `return 0;` is also a statement.
  - The computer executes the first statement, then the second, then the third….
- Each C++ statement is ended with a **semicolon** (`;`).
  - There are two statements in this main function.

```
#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0;
}
```

`cout` and `<<`

```
cout << "Hello World! \n";
```

- `cout` is a pre-defined object for “console output”.
  - It sends whatever data passed to it to the standard display device.
  - Typically this is a computer screen in the console mode.
- The **insertion operator `<<`** marks the direction of data flow.
  - Data “flow” like streams.
- `"Hello world! \n"` is a **string**.
  - Characters within a pair of **double quotation marks** form a string.
- `cout << "Hello world! \n"`:
  - Let the string `"Hello world! \n"` flow to the screen. The character `H` first, then `e`, then `l`.…

The escape sequence \n

```
cout << "Hello World! \n";
```

- But wait… what is that "**\n**"?
- In C++, the **slash** symbol "\" starts an **escape sequence**.
  - An escape sequence represents a "special character" that does not exist on the keyboard.
  - The **newline character** **\n** in C++ means "changing to a new line".
  - To see this, try the following codes:

```
cout << "Hello World! \n";
cout << "I love C++\n  so much!";
```

Escape sequences

- Some common escape sequences are listed below:

Escape sequence	Effect	Escape sequence	Effect
`\n`	A new line	`\\`	A slash: `\`
`\t`	A horizontal tab	`\'`	A single quotation: `'`
`\b`	A backspace	`\"`	A double quotation: `"`
`\a`	A sound of alert		

Concatenated data streams

- The insertion operator **<<** can be used to **concatenate** multiple data streams in one single statement.
  - The two statements

```
cout << "Hello World! \n";
cout << "I love C++\n  so much!";
```

    and this statement

```
cout << "Hello World! \n" << "I love C++\n  so much!";
```

    display the same thing.

- Note that the statement

```
"Hello World!" >> cout;
```

  is wrong!

Our first C++ program as a whole

- This is our first C++ program:

```
#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0;
}
```

- Go modify the statements by yourself!

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The cin object

- The **cout** object prints out data to the console output.
- Another object, **cin**, accepts data **input** (by the user or other programs) from the console input (typically the keyboard).
- In order to use the **cin** object, we need to first prepare a "**container**" for the input data. The thing we need is a **variable**.
- When we use a single variable to receive the data, the syntax is

```
cin >> variable;
```

  - In this week, you will use the **cin** object to **interact** with your program.
  - In the future, you will use **cin** to read testing data of your program.
- Let's first learn how to **declare variables**.

Variables and data types

- A variable is a container that stores a value.
  - Once we declare a variable, the system allocates a **memory space** for it.
  - A value may then be stored in that space.
- In C++, each variable must be specified a **data type**.
  - It tells the system how to allocate memory spaces.
  - It tells the system how to interpret those 0s and 1s stored there.
- The data type will also determine how **operations** are performed on the variable.
- Four attributes of a (typical) variable:
  - Type.
  - Name.
  - Value.
  - Address.

Basic data types

- There are ten **basic** (or **built-in** or **primitive**) data types in C++.
  - They are provided as part of the C++ standard.

Category	Type	Bytes	Type	Bytes
Integers	`bool`	1	`long`	4
	`char`	1	`unsigned int`	4
	`int`	4	`unsigned short`	2
	`short`	2	`unsigned long`	4
Fractional numbers	`float`	4	`double`	8

- There are ten basic data types, belonging to two categories.
  - The number of bytes is **compiler-dependent**.
- Today let's use integer and Boolean variables only.

Variable declaration

- Before we use a variable, we must first **declare** it.
  - We need to specify its **name** and **data type**.
- The syntax of a variable declaration statement is

```
type variable name;
```

  - For example,

```
int myInt;
```

  declares an integer variable called **myInt**.
- A variable name is an **identifier**.
  - We do not need to memorize the memory address (which is a sequence of numbers).
  - We access the space through the variable name.

Address	Identifier	Value
0x22fd4c	myInt	???

Memory

Declaration and assignment

- Beside declaring a variable, we may also **assign** values to a variable.
  - `int myInt;` declares an integer variable.
  - `myInt = 10;` **assigns 10 to `myInt`**.
- We may do these together:

```
type variable name = initial value;
```

  - `int yourInt = 5;` declares an integer variable `yourInt` and assigns 5 to it.
  - The assignment is called **initialization** if it is done with declaration.
- Without initialization, the variable may be of **any value** (depending on what was left since the last time this space is used)!

Address	Identifier	Value
0x20c648	yourInt	5
0x22fd4c	myInt	10

Memory

The assignment operator

- In the statement

```
myInt = 10;
```

  we use the **assignment operator** `=` to assign 10 to `myInt`.
  - This is an assignment **operation**.
- In general, an operation has **operators** and **operands** involved:
  - An operator (1) takes one or a few operands as inputs, (2) make some things happen to them, and then (3) return a value.
- For the assignment operation:
  - The two operands are **a variable** (the “l-value”) and **a value** (the “r-value”).
  - The variable’s value will **become the given value**.
  - The **assigned value** will be returned (but ignored in this example).

More about variable declaration

- We may declare multiple variable in the same type together:
  - **`int a, b, c;`** declares three integers **`a`**, **`b`**, and **`c`**.
- We may initialize all of them also in a single statement:
  - **`int a = 1, b = 2, c = 3;`**
- A variable's name consists of a consecutive sequence of letters, digits, and the underline symbol "**_**".
  - It cannot begin with a number.
  - It cannot be the same as a C++ **keywords** (cf. Figure 3.3 of the textbook).
  - It (and the whole C++ world) is **case-sensitive**.
- **Always** initialize your variables (e.g., 0).
- Use meaningful names (e.g., **`yardToInch`** is) better than **`y`**).
- **Capitalize** the first character of each word, but not the very first one.
  - **`int yardToInch = 12, avgGrade = 0, maxGrade = 100;`**

Our 2nd C++ program (in progress)

- This is our second C++ program (to be completed later):
- We first declare and initialize two integers.
- We then do

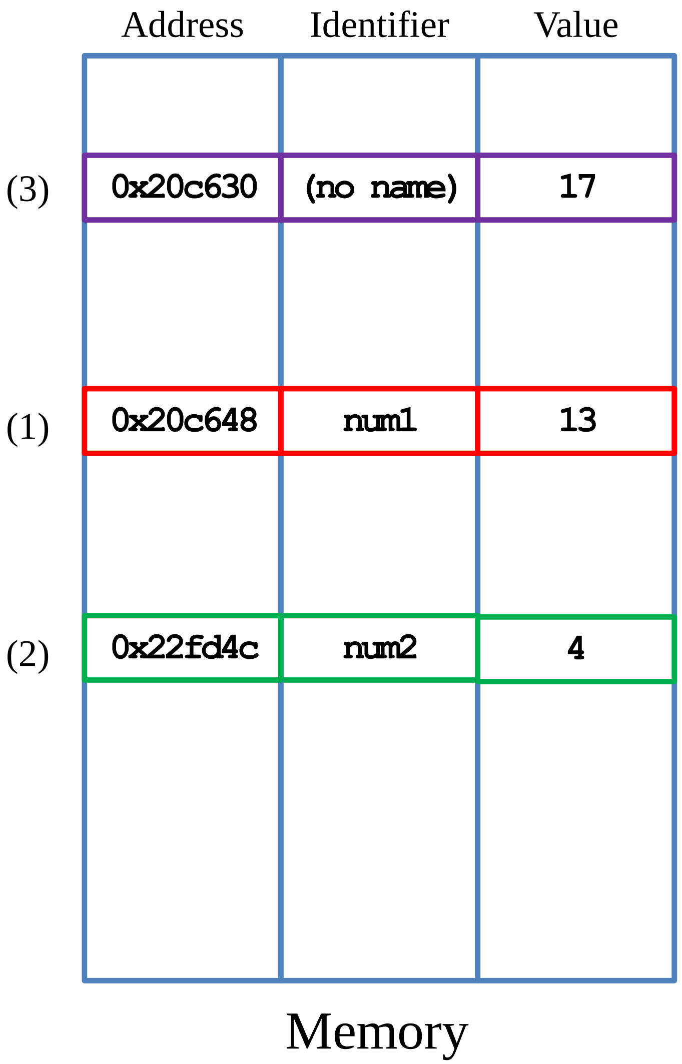
```
cout << num1 + num2;
```

- There are two **operations** here:
  - **num1 + num2** is an addition operation. The sum will be **returned** to the program.
  - That returned value is then sent to **cout** through **<<**.
- As a result, **17** is displayed on the screen.

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 13, num2 = 4;
  cout << num1 + num2;

  return 0;
}
```

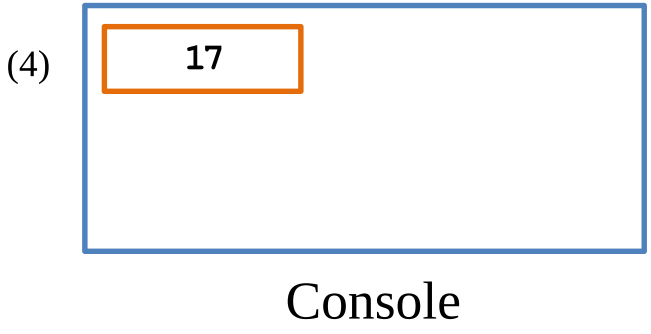
When we execute this program

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 13, num2 = 4;
  cout << num1 + num2;

  return 0;
}
```



	Address	Identifier	Value
(3)	0x20c630	(no name)	17
(1)	0x20c648	num1	13
(2)	0x22fd4c	num2	4

Memory



(4)

```
17
```

Console

Our 2nd C++ program (in progress)

- Let’s make the output look better:

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 13, num2 = 4;
  cout << "The sum of " << num1 << " and " << num2 << " is "
       << num1 + num2 << "\n";

  return 0;
}
```

- How would you interpret the program?

Our 2nd C++ program (in progress)

- There are other arithmetic operations:
  - Addition, subtraction, multiplication, division, and modulus.
- What will be displayed on the screen?
- Data types matter!
  - If the inputs of the division operation are both integers, the output will be **truncated** to an integer.
  - We will discuss this in details later in this semester.

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 13, num2 = 4;

  cout << num1 + num2 << "\n";
  cout << num1 - num2 << "\n";
  cout << num1 * num2 << "\n";
  cout << num1 / num2 << "\n";
  cout << num1 % num2 << "\n";

  return 0;
}
```

Our second C++ program

- Now we are ready to present our second C++ program:

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 0, num2 = 0;

  cout << "Please enter one number: ";
  cin >> num1;
  cout << "Please enter another number: ";
  cin >> num2;

  cout << "The sum is " << num1 + num2;

  return 0;
}
```

The cin object

- In this example, we allow the user to enter two numbers.
- We declare two variables to receive the inputs.
- We then use the **cin** object to send input values into the variables.

```
cout << "Please enter one number: ";
cin >> num1;
cout << "Please enter another number: ";
cin >> num2;
```

  - The **cout** statements are **prompts**: a message telling the user what to do.
  - The input of a value ends when the user press “enter”.
- The variables (and their values) can then be used in other statements.

```
cout << "The sum is " << num1 + num2;
```

The `cin` object

- The **extraction operator >>** is used with the **cin** object.
- One cannot use **cout** with **>>** or **cin** with **<<**!
  - Both statements here are wrong:

```
a >> cout;
b << cin;
```

- The input stream is split into multiple pieces by “enter” and white spaces.
  - Different pieces are sent to different variables.
  - If the number of variables is fewer than the input pieces, pieces will be put in an **input buffer** waiting for future **cin** operations.
- Try to run the program by entering “**4 13**”.

Our second C++ program

- Another way to implement this program:

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 0, num2 = 0;

  cout << "Please enter two numbers, separated by a white space: ";
  cin >> num1 >> num2;

  cout << "The sum is " << num1 + num2;

  return 0;
}
```

- `>>` may send (pieces of) values to multiple variables.
- Data types matter: What if we enter “`1.3 4`”?

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Our third C++ program (in progress)

- Would you guess what does this program do?
- We use the **if** statement to control the sequence of executions.

```
if (condition)
{
  statements
}
```

  - If ***condition*** returns **true**, do ***statements*** sequentially.
  - Otherwise, skip those ***statements***.
- What is ==?

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 0, num2 = 0;

  cout << "Please enter two numbers, "
       << "separated by a white space: ";
  cin >> num1 >> num2;

  if (num1 > num2)
    cout << "The larger one is " << num1;
  if (num1 < num2)
    cout << "The larger one is " << num2;
  if (num1 == num2)
    cout << "The two are equal";

  return 0;
}
```

The comparison operators

- **==** checks whether the two sides of it are **equal**.
  - Returns a **Boolean** value: true (non-zero) or false (zero).
- **=** and **==** are different!
  - When we write **a = 20**, it assigns 20 to **a**. The value 20 is then returned.
  - When we write **a == 20**, it checks whether **a** equals 20. Either **true** or **false** is then returned.
  - What happens to the following three programs?

```
int a = 0;
if(a == 1)
{
  cout << "here!";
}
```

```
int a = 0;
if(a = 1)
{
  cout << "here!";
}
```

```
int a = 0;
if(a = 0)
{
  cout << "here!";
}
```

- Do distinguish “**becomes**” and “**equals**”!
  - **a = 20** is read as “**a** becomes 20”. **a == 20** is read as “**a** equals 20”.

The comparison operators

- All the following comparison operators return a Boolean value.
  - **`>`**: bigger than
  - **`<`**: smaller than
  - **`>=`**: not smaller than
  - **`<=`**: not bigger than
  - **`==`**: equals
  - **`!=`**: not equals

The `if` statement

- In an **`if`** block, there may be **multiple** statements.
- A pair of **curly brackets** are used to define the block.

```
int a = 0;
if(a == 1)
{
  cout << "he";
  cout << "re!";
}
```

- We may drop **`{ }`** if, and only if, there is **only one** statement under the if statement.

```
int a = 0;
if(a == 1)
  cout << "here!";
```

- What will happen to this program?

```
int a = 0;
if(a == 1)
  cout << "he";
  cout << "re!";
```

Our third C++ program

- Would you guess what does this program do?
- We use the **while** statement to **repeat** several statements.

```
while (condition)
{
  statements
}
```

  - If *condition* returns **true**, do *statements* sequentially and then go back to check *condition* again.
- What is **num1 = num1 - 1**?

```
#include <iostream>
using namespace std;

int main()
{
  int num1 = 0, num2 = 0;
  cout << "Please enter two numbers, "
       << "separated by a white space: ";
  cin >> num1 >> num2;

  while (num1 > num2)
  {
    cout << "number 1 is " << num1 << "\n";
    num1 = num1 - 1;
  }

  return 0;
}
```

The while statement

- while is nothing but an if that repeats.
- Consider the assignment operator = again:

```
num1 = num1 - 1;
```

  - Read it as “becomes”: **num1** becomes **num1** minus 1.
  - First, **num1 - 1** is calculated and returned by the subtraction operator **-**.
  - This value is then assigned to **num1**.
- Now we fully understand this program:

```
while (num1 > num2)
{
  cout << "number 1 is " << num1 << "\n";
  num1 = num1 - 1;
}
```

Syntax errors vs. logic errors

- A **syntax error** occurs when the program does not follow the standard of the programming language.

```
if (num1 > num2)
  cout << "The larger one is << num1;
if (num1 < num2)
  cout << "The larger one is " << num2
```

  - The compiler detects syntax errors.
- A **logic error** occurs when the program does not run as the programmer expect.

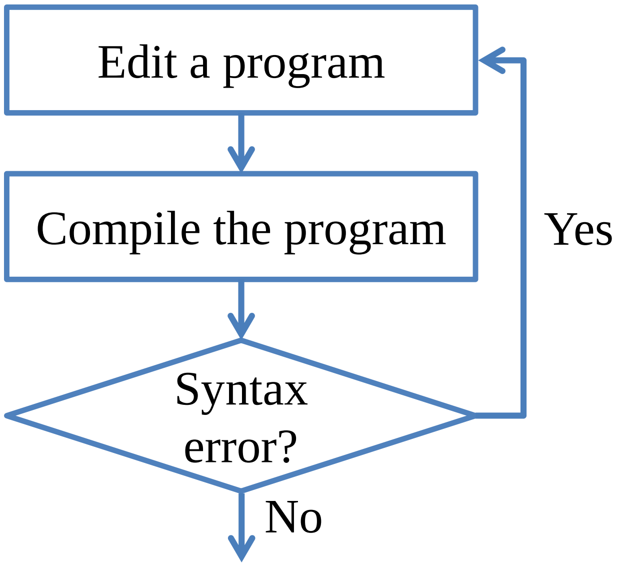
```
if (num1 > num2)
  cout << "The larger one is " << num1;
if (num1 < num2)
  cout << "The larger one is " << num1;
```

  - Programmers must detect logic errors by themselves.
  - The process is called **debugging**.

Steps to do computer programming

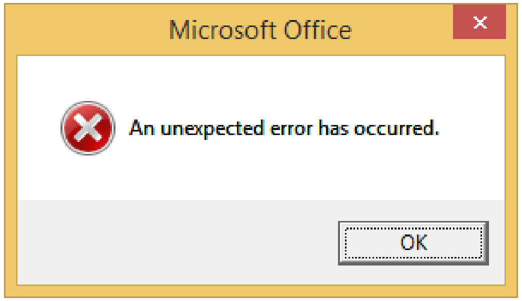
- (The following XXX pages of slides are modified from the lecture notes by Professor Pangfeng Liu in NTU CSIE.)

- First, **edit** a program.
- Second, **compile** the program.
- If there is a **syntax error**, fix it.

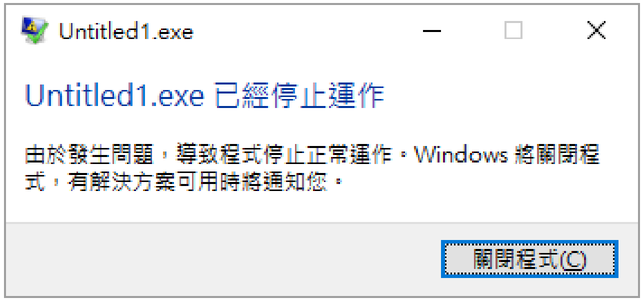


Steps to do computer programming

- Next, **execute** the program.
- Be aware of **runtime errors**:
  - A runtime error is one kind of logic error.
  - When it happens, the program **cannot terminate as we expect**.



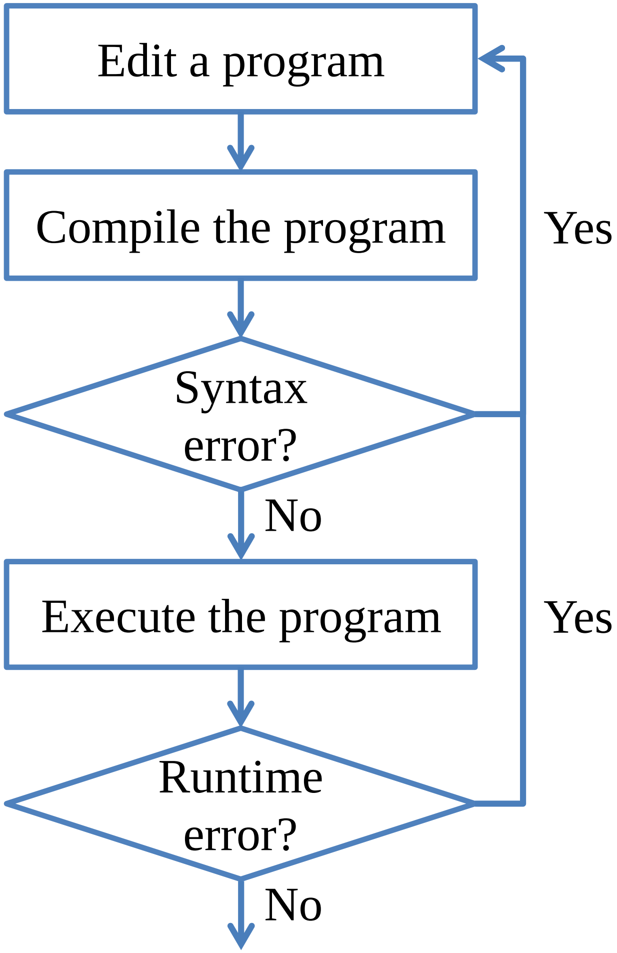
An unexpected error has occurred.



Untitled1.exe 已經停止運作

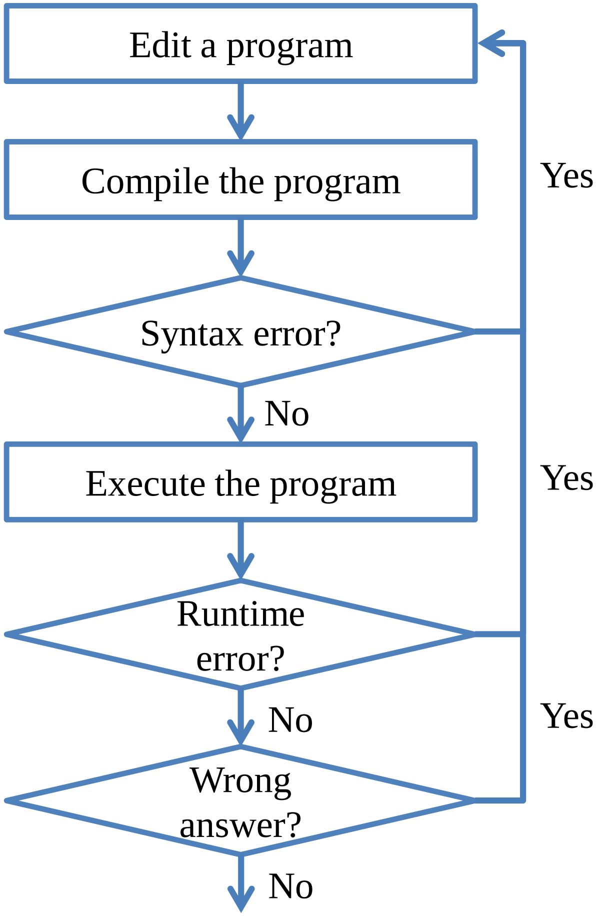
由於發生問題，導致程式停止正常運作。Windows 將關閉程式，有解決方案可用時將通知您。

- If there is a runtime error, fix it.
  - Mostly a runtime error occurs at the **memory level**.



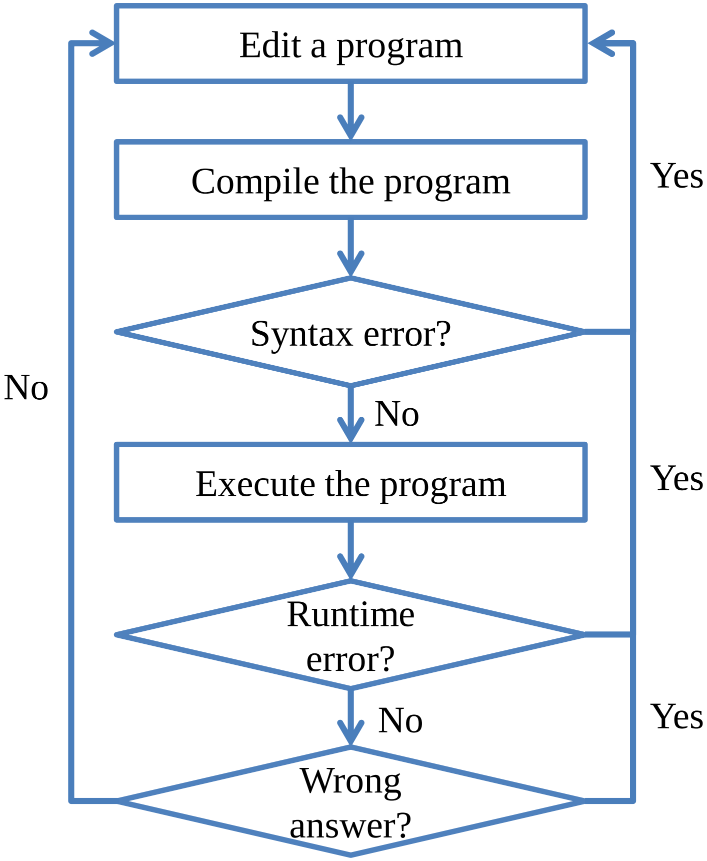
Steps to do computer programming

- Now your program terminates successfully.
- Next, check your answer.
  - You get a **wrong answer** if the outcome is incorrect.
  - Wrong answer is one kind of logic error.
- If there is a wrong answer, fix it.
  - Typically the most time consuming step.
  - **Logic**!



Steps to do computer programming

- Now the answer is correct. What is the **next step**?
- Write your **next program**!



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- **Formatting a C++ program**

Formatting a C++ program

- In a C++ program, semicolons are marks of the end of statements.
- White spaces, tabs, and new lines do not affect the compilation and execution of a C++ program.
  - Except strings and preprocessor commands.
- The following two programs are equivalent. Which one do you prefer?

```
#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0;
}
```

```
#include <iostream>
using namespace
std; int main
(){cout << "Hello
World! \n“;return 0;}
```

Formatting a C++ program

- Maintaining the program in a good **format** is very helpful.
- While each programmer may have her own programming style, there are some general guidelines.
  - Start a new line after each semicolon.
  - Align paired braces vertically.
  - Indent blocks according to their levels.
  - Give variables understandable names.
  - Declare related variables in the same line.
  - Add proper white spaces and empty lines.
  - Write comments.

Formatting a C++ program

- Start a **new line after** each semicolon. Do not put two statements in one line!
- **Align** paired braces vertically.
  - Which one do you prefer?

```
int main()
{
  int a = 5;
  if(a < 5)
  {
    cout << "...";
    cout << "...";
  }
  return 0;
}
```

```
int main() {
  int a = 5;
  if(a < 5) {
    cout << "...";
    cout << "...";
  }
  return 0;
}
```

```
int main()
{
  int a = 5;
  if(a < 5)
  {
    cout << "...";
    cout << "...";
}
  return 0;
  }
```

- Both the first and second way are acceptable.

Indentions

- **Indent** blocks according to their levels.
  - Which one do you prefer?

```
int main()
{
  int a = 5;
  if(a < 5)
  {
    cout << "...";
    cout << "...";
  }
  return 0;
}
```

```
int main()
{
int a = 5;
if(a < 5)
{
cout << "...";
cout << "...";
}
return 0;
}
```

```
int main()
{
  int a = 5;
  if(a < 5)
  {cout << "...";
 cout << "...";
  }
    return 0;
}
```

Variable declaration

- When declare variables:
  - Give variables **understandable names**.
  - Declare related variables **in the same line**.
- Which one do you prefer?

```
int main()
{
  int dice1 = 0, dice2 = 0;
  int sum = 0;
  cin >> dice1 >> dice2;
  sum = dice1 + dice2;
  cout << sum << "\n";
  return 0;
}
```

```
int main()
{
  int a, b, c;
  cin >> a >> b;
  c = a + b;
  cout << c << "\n";
  return 0;
}
```

Write spaces and empty lines

- Some suggestions about white spaces and empty lines are useful.
  - Add **two white spaces** around a binary operator.
  - Add a white space after each comma.
  - Use **empty lines** to separate groups of codes.
- Which one do you prefer?

```
int main()
{
  int dice1 = 0, dice2 = 0;
  int sum = 0;

  cin >> dice1 >> dice2;
  cout << sum << "\n";

  return 0;
}
```

```
int main()
{
  int dice1=0,dice2=0;
  int sum=0;
  cin>>grade1>>grade2;
  cout<<sum<<"\n“;
  return 0;
}
```

Comments

- **Comments** are programmers' **notes** and will be ignored by the compiler.
- In C++, there are two ways of writing comments:
  - A single line comment: Everything following a `//` in the same line are treated as comments.
  - A block comment: Everything within `/*` and `*/` (may across multiple lines) are treated as comments.

```
/* Ling-Chieh Kung's work
   for the first lecture */

#include <iostream>
using namespace std;

int main()
{
  cout << "Hello World! \n";
  return 0; // the program terminates correctly
}
```